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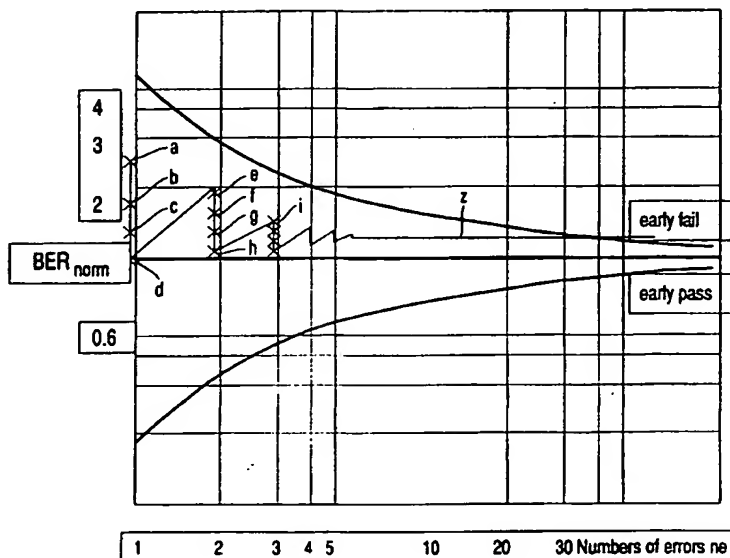
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For two-letter codes and other abbreviations, refer to the "Guid-
ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.(75) Inventors/Applicants (*for US only*): **MAUCKSCH,**

(54) Title: METHOD FOR TESTING THE ERROR RATIO OF A DEVICE

BER_{limit} = 0.2 (1/5) Actual BER = 0.25 (1/4)

Number of sample,	1	2	3	4	5	6	7	8	9	10 etc...
Sequence, 0: correct, 1: error	0	1	0	0	0	1	0	0	0	1
BER		1/2	1/3	1/4	1/5	2/6	2/7	2/8	2/9	3/10
BER _{norm}		5/2	5/3	5/4	5/5	10/6	10/7	10/8	10/9	15/10



(57) Abstract: A method for testing the (Bit) Error Ratio BER of a device against a maximal allowable (Bit) Error Ratio BER_{limit} with an early pass and/or early fail criterion, whereby the early pass and/or early fail criterion is allowed to be wrong only by a small probability D. ns bits of the output of the device are measured, thereby ne erroneous bits of these ns bits are detected. PD_{high} and/or PD_{low} are obtained, whereby PD_{high} is the worst possible likelihood distribution and PD_{low} is the best possible likelihood distribution containing the measured ne erroneous bits with the probability D. The average numbers of erroneous bits NE_{high} and NE_{low} for PD_{high} and PD_{low} are obtained. NE_{high} and NE_{low} are compared with NE_{limit} = BER_{limit} × ns. If NE_{limit} is higher than NE_{high} or NE_{limit} is lower than NE_{low} the test is stopped.

Method for testing the Error Ratio of a Device

The application is related to testing the (Bit) Error Ratio of a device, such as a digital receiver for mobile phones.

5

Concerning the state of the art, reference is made to US 5,606,563. This document discloses a method of determining an error level of a data channel comprised of receiving channel parity error data indicating when bit errors occur
10 within a set of data carried on the channel (channel error events), successively integrating the channel error events data over successive accumulation periods, comparing the integrated channel error events data with a threshold, and indicating an alarm in the event the integrated channel
15 error events data exceeds the threshold.

Testing digital receivers is two fold: The receiver is offered a signal, usually accompanied with certain stress conditions. The receiver has to demodulate and to decode
20 this signal. Due to stress conditions the result can be partly erroneous. The ratio of erroneously demodulated to correctly demodulated bits is measured in the Error Ratio test. The Bit Error Ratio BER test or more general any error rate test, for example Frame Error Ratio FER, Block
25 Error Ratio BLER each comprising a Bit Error test, is subject of this application.

BER testing is time consuming. This is illustrated by the following example: a frequently used BER limit is 0.001.
30 The bitrate frequently used for this test is approx. 10kbit/s. Due to statistical relevance it is not enough to observe 1 error in 1000 bits. It is usual to observe approx. 200 errors in 200 000 bits. This single BER test lasts 20 seconds. There are combined tests which contain
35 this single BER test several times, e.g. the receiver blocking test. Within this test the single BER test is repeated 12750 times with different stress conditions. Total test time here is more than 70h. It is known in the state of the art to fail the DUT (Device Under Test) early

only, when a fixed number of errors as 200 errors are observed before 200 000 bits are applied. (Numbers from the example above).

- 5 It is the object of the present application to propose a method for testing the Bit Error Ratio of a device with reduced test time, preserving the statistical relevance.

The object is solved by the features of claim 1 or claim 4.

10

- According to the present invention, the worst possible likelihood distribution PD_{high} and/or the best possible likelihood distribution PD_{low} are obtained by the formulas given in claim 1 and 4, respectively. From these likelihood
15 distributions, the average number NE_{high} or NE_{low} is obtained and compared with the limit NE_{limit} , respectively. If the limit NE_{limit} is higher than the average number NE_{high} or smaller than the average number NE_{low} , the test is stopped and it is decided that the device has early passed or early
20 failed, respectively.

The dependent claims contain further developments of the invention.

- 25 The Poisson distribution preferably used for the present invention, is best adapted to the BER problem. The nature of the Bit Error occurrence is ideally described by the binomial distribution. This distribution, however, can only be handled for small number of bits and errors. For a
30 high number of bits and a low Bit Error Ratio the binomial distribution is approximated by the Poisson distribution. This prerequisite (high number of bits, low BER) is ideally fulfilled for normal Bit Error Rate testing (BER limit 0.001) as long as the DUT is not totally broken (BER 0.5).
35 The application proposes to overcome problems with the discrete nature of the Poisson distribution. With the same method an early pass condition as well as an early fail condition is derived.

An embodiment of the invention is described hereafter. In the drawings

5 Fig. 1 shows a diagram to illustrate the inventive method,

Fig. 2 shows the referenced Bit Error Ratio ber_{norm} as a function of the measured errors ne ,

10 Fig. 3 shows a diagram to illustrate a measurement using a first embodiment of the inventive method,

Fig. 4 shows a diagram to illustrate a measurement using a second embodiment of the inventive method and

15 Fig. 5 shows a diagram illustrating the position at the end of the test using the first embodiment of the inventive method as a function of probability.

20 In the following, the early fail condition and the early pass condition is derived with mathematical methods.

Due to the nature of the test, namely discrete error events, the early stop conditions are declared not valid,
25 when fractional errors < 1 are used to calculate the early stop limits. The application contains proposals, how to conduct the test at this undefined areas. The proposals are conservative (not risky). A DUT on the limit does not achieve any early stop condition. The application proposes
30 to stop the test unconditioned at a specific number K (for example 200 bit) errors. As this proposal contains a pseudo paradox, an additional proposal to resolve this pseudo paradox is appended.

35 Based on a single measurement, a confidence range CR around this measurement is derived. It has the property that with high probability the final result can be found in this range.

The confidence range CR is compared with the specified BER limit. From the result a diagram is derived containing the early fail and the early pass condition.

5 With a finite number of samples n_s of measured bits, the final Bit Error Ratio BER cannot be determined exactly. Applying a finite number of samples n_s , a number of errors n_e is measured. $n_e/n_s = \text{ber}$ is the preliminary Bit Error Ratio.

10

In a single test a finite number of measured bits n_s is applied, and a number of errors n_e is measured. n_e is connected with a certain differential probability in the Poisson distribution. The probability and the position in
15 the distribution conducting just one single test is not known.

Repeating this test infinite times, applying repeatedly the same n_s , the complete Poisson distribution is obtained. The
20 average number (mean value) of errors is NE . NE/n_s is the final BER. The Poisson distribution has the variable n_e and is characterised by the parameter NE , the average or mean value. Real probabilities to find n_e between two limits are calculated by integrating between such limits. The width of
25 the Poisson distribution increases proportional to $\text{SQR}(NE)$, that means, it increases absolutely, but decreases relatively.

In a single test n_s samples are applied and n_e errors are
30 measured. The result can be a member of different Poisson distributions each characterized by another parameter NE . Two of them are given as follows:

The worst possible distribution NE_{high} , containing the
35 measured n_e with the probability D_1 , is given by

$$D_1 = \int_0^{n_e} PD_{\text{high}}(NE_{\text{high}}, ni) dni \quad (1)$$

In the example D_1 is $0.002=0.2\%$ PD_{high} is the wanted Poisson distribution with the variable ni . ne is the measured number of errors.

- 5 The best possible distributions NE_{low} , containing the measured ne with the probability D_2 is given by

$$D_2 = \int_{ne}^{\infty} PD_{low}(NE_{low}, ni) dni \quad (2)$$

10

In the example D_2 is equal D_1 and it is $D = D_1 = D_2 = 0.002=0.2\%$.

- 15 To illustrate the meaning of the range between NE_{low} and NE_{high} refer to Fig. 1. Fig. 1 shows the likelihood density PD as a function of the measured number of errors ne . In the example, the actual detected number of errors ne within the measured sample of ns bits is 10. The likelihood
 20 distribution of the errors is not known. The worst possible likelihood distribution PD_{high} under all possible likelihood distributions as well as the best possible likelihood distribution PD_{low} under all possible likelihood distributions are shown. The worst possible likelihood
 25 distribution PD_{high} is characterized in that the integral from 0 to $ne = 10$ gives a total probability of $D_1 = 0.002$. The best possible likelihood distribution PD_{low} is characterized in that the integral from $ne = 10$ to ∞ gives a total probability of $D_2 = 0.002$. In the preferred
 30 embodiment D_1 is equal to D_2 , i.e. $D_1 = D_2 = 0.002 = 0.2\%$. After having obtained the likelihood distribution PD_{high} and PD_{low} from formulas (1) and (2), the average values or mean values NE_{high} for the likelihood distribution PD_{high} and NE_{low} for the likelihood distribution PD_{low} can be obtained.
 35 The range between the mean value NE_{low} and NE_{high} is the confidence range CR indicated in Fig. 1.

In the case the measured value ne is a rather untypical result (in the example just 0.2% probability) nevertheless the final result NE can still be found in this range, called confidence range CR .

5

The probabilities D_1 and D_2 in (1) and (2) can be independent, but preferable they are dependent and equal ($D = D_1 = D_2$).

10 For the Poisson distribution NE_{low} and NE_{high} can be obtained. With the formulas (3) and (4) respectively the inputs are the number of errors ne , measured in this test and the probabilities D and $C = 1 - D$. The Output is NE , the parameter describing the average of the Poisson
15 distribution.

The following example is illustrated in Fig. 1 ($D = D_1 = D_2$):

$$20 \quad NE_{low} = \frac{qchisq(D, 2 \cdot ne)}{2} \quad (3)$$

$$NE_{high} = \frac{qchisq(C, 2(ne + 1))}{2} \quad (4)$$

Example:

25

Number of errors: $ne=10$

Probability: $D=0.002$ $C=0.998$

Result:

30

$NE_{low} = 3.26$

$NE_{high} = 22.98$

Interpretation:

35 Having measured $ne=10$ errors in a single test, then with a low probability $D=0.002$ the average number of errors NE in this test is outside the range from 3.26 to 22.98 or with a

high probability $C=0.998$ inside this range from 3.26 to 22.98.

Such as the width of the Poisson distribution, the
5 confidence range CR increases proportional to $SQR(ne)$, that means, it increases absolutely, but decreases relatively.

If the entire confidence range CR, calculated from a single
result ne , is found on the good side ($NE_{limit} > NE_{high}$) of
10 the specified limit NE_{limit} we can state: With high probability C , the final result NE is better than the limit NE_{limit} . Whereby NE_{limit} is given by

$$NE_{limit} = BER_{limit} \cdot ns \quad (5)$$

15

and BER_{limit} is the Bit Error Rate allowable for the device and obtained by an ideal long test with an infinite high number of bit samples ns .

20 If the entire confidence range CR, calculated from a single result ne , is found on the bad side ($NE_{limit} < NE_{low}$) of the specified limit NE_{limit} we can state: With high probability C , the final result NE is worse than the limit.

25 With each new sample and/or error a new test is considered, reusing all former results. With each new test the preliminary data for ns , ne and ber is updated. For each new test the confidence range CR is calculated and checked against the test limit NE_{limit} .

30

Once the entire confidence range CR is found on the good side of the specified limit ($NE_{limit} > NE_{high}$), an early pass is allowed. Once the entire confidence range CR is found on the bad side of the specified limit ($NE_{limit} < NE_{low}$) an
35 early fail is allowed. If the confidence range CR is found on both sides of the specified limit ($NE_{low} < NE_{limit} < NE_{high}$), it is evident neither to pass nor to fail the DUT early.

Fig. 1 illustrates the above conditions. Of course, NE_{limit} is a fixed value not altering during the test, but NE_{low} and NE_{high} as well as the confidence range CR are altering during the test. For reasons of illustration, however, the three possibilities of the possible positions of the confidence range CR with respect to the constant limit NE_{limit} are drawn for the same example in Fig. 1.

The above can be described by the following formulas:

10

The current number of samples ns is calculated from the preliminary Bit Error Ratio ber and the preliminary number of errors ne

15

$$ber = ne/ns \quad (6)$$

After a full test the final Bit Error Ratio is

20

$$BER_{limit} = NE_{limit} / ns \quad (7)$$

for abbreviation in the formula:

25

$$ber_{norm} = ber / BER_{limit} = ne / NE_{limit} \quad (8)$$

(normalised ber)

Early pass stipulates:

$$NE_{high} < NE_{limit} \quad (9)$$

30 Early fail stipulates:

$$NE_{low} > NE_{limit} \quad (10)$$

Formula for the early pass limit:

35

$$ber_{norm} = \frac{ne}{NE_{high}} \quad (11)$$

This is the lower curve ($ber_{norm_{pass}}(ne, C)$) in Fig. 2, which shows ber_{norm} as a function of ne .

Formula for the early fail limit:

5

$$ber_{norm} = \frac{ne}{NE_{low}} \quad (12)$$

This is the upper curve ($ber_{norm_{fail}}(ne, D)$) in Fig. 2.

- 10 As the early pass limit is not defined for $ne = 0$ (normally the case at the very beginning of the test for a good DUT), an artificial error event with the first sample can be introduced. When the first real error event occurs, the artificial error is replaced by this real one. This gives
- 15 the shortest possible measurement time for an ideal good DUT. For example $ns=5000$ for $BER_{limit} = 0.001$ and probability $D = D_1 = D_2 = 0.2\%$.

- As the early fail limit uses $NE_{low} < 1$ for small $ne < k$ (in
- 20 the example below $k=5$) due to a decision problem at a fractional error, the early fail limit at $ne=k$ is extended with a vertical line upwards. This ensures that a broken DUT hits the early fail limit in any case after a few samples, approx. 10 in the example. In other words, the
- 25 test is not stopped as long as ne is smaller than k .

- With each new sample and/or error a new test is considered, reusing all former results. With each new test the preliminary data for ns , ne and ber and ber_{norm} are updated
- 30 and a ber_{norm}/ne coordinate is entered into the ber_{norm} -diagram. This is shown in Fig. 3. Once the trajectory crosses the early fail limit ($ber_{norm}(ne, D)$) or the early pass limit ($ber_{norm}(ne, C)$) the test may be stopped and the conclusion of early fail or early pass may be drawn based
- 35 on this instant.

Fig. 3 shows the curves for early fail and early pass. ber_{norm} is shown as a function of the number of errors ne .

For the simple example demonstrated in Fig. 3, it is $BER_{limit} = 0.2 = 1/5$ and the final Bit Error Ratio $BER = 0.25 (1/4)$. The test starts with the first bit sample, for which no error is detected. For the second sample, a first error is detected and the preliminary Bit Error Ratio $ber = ne/ns = 1/2$ and $ber_{norm} = ber/BER_{limit}$ becomes $1/2 : 1/5 = 5/2$. ber_{norm} after the second sample is marked with a cross a in Fig. 3. For the third, fourth and fifth sample, no further error occurs and ber_{norm} subsequently becomes $5/3$, $5/4$ and $5/5$, respectively, which is marked with the crosses b, c and d in Fig. 3, respectively. The sixth sample brings a new error and ne becomes 2. Consequently, $ber = ne/ns$ becomes $2/6$ and ber_{norm} becomes $10/6$. This situation is marked with cross e in Fig. 3. For the seventh, eighth and ninth sample, no further error occurs and the situation after the seventh, eighth and ninth sample is marked with crosses f, g, h in Fig. 3, respectively. The tenth sample brings a third error. Consequently, ber becomes $3/10$ and ber_{norm} becomes $15/10$. This situation is marked with cross i in Fig. 3. As can be seen from Fig. 3, the trajectory is between the early fail curve and the early pass curve at the beginning of the test, but converges to a line Z, which crosses the early fail curve after about forty errors. After forty errors, it can thus be decided that the tested DUT early fails the test.

If no early stop occurs the BER test may be stopped, after the following condition is valid:

$$ne \geq K \quad (13)$$

and the DUT shall be passed, if ns is sufficiently high. K is a maximum number of errors. For example K can be 200.

If the trajectory neither crosses the early fail curve nor the early pass curve after K (for example 200) errors have occurred, the DUT can be finally passed. If the DUT, however, is rather good or rather bad, the tests can be

stopped much earlier, long before the $K = 200$ errors have occurred. This significantly shortens the total test time.

In the above embodiment early fail means: a DUT is failed
 5 and a probability of 0.2 % that it is actually better than the limit is accepted. Further early pass means: the DUT is passed and a probability of 0.2 % that it is actually worse than the limit is accepted. If the test is stopped at 200 errors the DUT is passed without any early fail or early
 10 pass condition arbitrarily. It can cross the vertical 200 error line in Fig. 2 at different heights, each height is connected with a certain statistical interpretation: The probability to have a DUT better (worse) than the limit is indicated in Fig. 5. The vertical in Fig. 5 shows the
 15 position in Fig. 2 at the end of the test. The horizontal in Fig. 5 shows the respective probability.

This embodiment contains a pseudo paradox, due to statistical nature of the test and limited test time,
 20 demonstrated with the following example: A DUT, which is early failed, would pass if the probability for a wrong decision has been reduced by widening the early stop limits, or vice versa, if the test is stopped at 200 errors and the DUT is arbitrarily failed. A DUT, which is early
 25 passed, would fail if the probability for a wrong decision has been reduced.

The following embodiment resolves this pseudo paradox and additionally accelerates the test. This is done by a
 30 meaningful redefinition of the early pass limit maintaining the early fail limit. Early pass means now: A DUT is passed and a probability of 0.2 % that it is actually worse than M times the specified limit ($M > 1$) is accepted. This is a worse DUT limit. This shifts the early pass limit upwards
 35 in Fig. 2 as shown in Fig. 4. $Bernorm_{pass}(ne, C)$ in Fig. 2 becomes $bernorm_{bad_{pass}}(ne, C)$ in Fig. 4. $Bernorm_{fail}(ne, D)$ remains unchanged. Now it is

$$NE_{limit,M} = BER_{limit} \cdot M \cdot ns$$

(14)

and an early pass is allowed, if $NE_{limit} \cdot M = NE_{limit,M} > NE_{high}$.

- 5 There are three high level parameters for the test:
- Probability to make a wrong decision (proposal: $C = 0.2 \%$)
 - Final stop (proposal: $K = 200$ errors)
 - Definition of a Bad DUT ($BER_{limit} \cdot M$)
- 10 These parameters are interdependent. It is possible to enter two of them and to calculate the third one. To make the test transparent, it is proposed to enter the wrong decision probability C and the final stop condition K and to derive the Bad DUT factor M . This is done in the
- 15 following manner: The early pass limit is shifted upwards by a factor of M , such that the early fail and the early pass limit intersect at 200 errors in the example as shown in Fig. 4. Fig. 4 also shows the test limit obtained from the crossing point from the early fail curve and the easy
- 20 pass curve, corresponding to M_{test} .

There are infinite possibilities to resolve the above mentioned paradox.

- 25 In the example above the open end between the limits was originally declared pass, and time was saved by multiplying the early pass limit with M ($M > 1$), shifting it upwards such that the early fail and the early pass curve intersect at 200 errors (200: example from above). Such only a DUT, bad
- 30 with high probability, is failed (customer risk).

- The complementary method is: The open end between the limits is declared fail, and time is saved by multiplying the early fail limit with m ($0 < m < 1$), shifting it downwards,
- 35 such that the early fail and the early pass curve intersect at 200 errors (200: example from above). Such only a DUT, good with high probability, is passed (manufacturer risk).

- The compromise method is: The open end between the limits is partitioned in any ratio: the upper part is declared fail and the lower part is declared pass. Time is saved by multiplying the early fail limit with m ($0 < m < 1$) and such shifting it downwards and by multiplying the early pass limit with M ($M > 1$) and such shifting it upwards. So the early fail and the early pass curve intersect at 200 errors (200: example from above).
- 10 With given D_1 and D_2 the early fail curve and the early pass curves in Fig. 3 and Fig. 2 or Fig. 4 can be calculated before the test is started. During the test only $ber_{norm} = ne/NE_{limit}$ has to be calculated and to be compared with the early pass limit and the early fail limit as explained with
- 15 respect to Fig. 3 and Fig. 4. Thus, no intensive calculation has to be done during the test.

Claims

1. Method for testing the Error Ratio BER of a device
 5 against a maximal allowable Error Ratio BER_{limit} with an early pass criterion, whereby the early pass criterion is allowed to be wrong only by a small probability D_1 , with the following steps
- measuring ns bits of the output of the device, thereby
 - 10 detecting ne erroneous bits of these ns bits,
 - assuming that the likelihood distribution giving the distribution of the number of erroneous bits ni in a fixed number of samples of bits is $PD(NE, ni)$, wherein NE is the average number of erroneous bits, obtaining PD_{high} from

15

$$D_1 = \int_0^{ne} PD_{high}(NE_{high}, ni) dni$$

- wherein PD_{high} is the worst possible likelihood distribution containing the measured ne erroneous bits with the
 20 probability D_1 ,
- obtaining the average number of erroneous bits NE_{high} for the worst possible likelihood distribution PD_{high} ,
 - comparing NE_{high} with $NE_{limit} = BER_{limit} \cdot ns$,
 - if NE_{limit} is higher than NE_{high} stopping the test and
 - 25 deciding that the device has early passed the test and
 - if NE_{limit} is smaller than NE_{high} continuing the test whereby increasing ns .

2. Method for testing the Error Ratio BER according to
 30 claim 1,
 characterized in that
 the likelihood distribution $PD(NE, ni)$ is the Poisson distribution.

- 35 3. Method for testing the Error Ratio BER according to claim 1 or 2,
 characterized in that

for avoiding a undefined situation for $ne=0$ starting the test with an artificial error $ne=1$ not incrementing ne then a first error occurs.

- 5 4. Method for testing the Error Ratio BER of a device against a maximal allowable Error Ratio BER_{limit} with an early fail criterion, whereby the early fail criterion is allowed to be wrong only by a small probability D_2 , with the following steps
- 10 - measuring ns bits of the output of the device, thereby detecting ne erroneous bits of these ns bits,
 - assuming that the likelihood distribution giving the distribution of the number of erroneous bits ni in a fixed number of samples of bits is $PD(NE,ni)$, wherein NE is the
 15 average number of erroneous bits, obtaining PD_{low} from the

$$D_2 = \int_{ne}^{\infty} PD_{low}(NE_{low}, ni) dni$$

- wherein PD_{low} is the best possible likelihood distribution
 20 containing the measured ne erroneous bits with the probability D_2 ,
 - obtaining the average number of erroneous bits NE_{low} for the best possible likelihood distribution PD_{low} ,
 - comparing NE_{low} with $NE_{limit} = BER_{limit} \cdot ns$,
 25 - if NE_{limit} is smaller than NE_{low} stopping the test and deciding that the device has early failed the test and
 - if NE_{limit} is higher than NE_{low} continuing the test whereby increasing ns .

- 30 5. Method for testing the Error Ratio BER according to claim 4,
 characterized in that
 the likelihood distribution $PD(NE,ni)$ is the Poisson distribution.

35

6. Method for testing the Error Ratio BER according to claim 4 or 5,
 characterized in that

for avoiding a undefined situation for $ne < k$, wherein k is a small number of errors, not stopping the test as long as ne is smaller than k .

- 5 7. Method for testing the Error Ratio BER according to claim 6,
characterized in that
 k is 5.

- 10 8. Method for testing the Error Ratio BER according to any of claims 4 to 7,
characterized by
an additional early pass criterion, whereby the early pass
criterion is allowed to be wrong only by a small
15 probability D_1 , with the following additional steps
- assuming that the likelihood distribution giving the
distribution of the number of erroneous bits ni in a fixed
number of samples of bits is $PD(NE, ni)$, wherein NE is the
average number of erroneous bits, obtaining PD_{high} from

20

$$D_1 = \int_0^{ne} PD_{high}(NE_{high}, ni) dni$$

- wherein PD_{high} is the worst possible likelihood distribution
containing the measured ne erroneous bits with the
25 probability D_1 ,

- obtaining the average number of erroneous bits NE_{high} for the worst possible likelihood distribution PD_{high} ,
- comparing NE_{high} with $NE_{limit} = BER_{limit} \cdot ns$,
- if NE_{limit} is higher than NE_{high} stopping the test and
- 30 deciding that the device has early passed the test and
- if NE_{limit} is smaller than NE_{high} continuing the test, whereby increasing ns .

9. Method for testing the Error Ratio BER according to
35 claim 8,
characterized in that

for avoiding a undefined situation for $ne=0$ starting the test with an artificial error $ne=1$ not incrementing ne then a first error occurs.

- 5 10. Method for testing the Error Ratio BER according to claim 8 or 9,
 characterized in that
 the probability D_1 for the wrong early pass criterion and
 the probability D_2 for the wrong early fail criterion are
 10 equal ($D_1=D_2$).

11. Method for testing the Error Ratio BER according to any
 of claims 4 to 7,
 characterized by
 15 an additional early pass criterion, whereby the early pass
 criterion is allowed to be wrong only by a small
 probability D_1 , with the following additional steps
 - assuming that the likelihood distribution giving the
 distribution of the number of erroneous bits ni in a fixed
 20 number of samples of bits is $PD(NE,ni)$, wherein NE is the
 average number of erroneous bits, obtaining PD_{high} from

$$D_1 = \int_0^{ne} PD_{high}(NE_{high}, ni) dni$$

- 25 wherein PD_{high} is the worst possible likelihood distribution
 containing the measured ne erroneous bits with the
 probability D_1 ,
 - obtaining the average number of erroneous bits NE_{high} for
 the worst possible likelihood distribution PD_{high} ,
 30 - comparing NE_{high} with $NE_{limit,M} = BER_{limit} \cdot M \cdot ns$, with
 $M > 1$
 - if $NE_{limit,M}$ is higher than NE_{high} stopping the test and
 deciding that the device has early passed the test and
 - if $NE_{limit,M}$ is smaller than NE_{high} continuing the test,
 35 whereby increasing ns .

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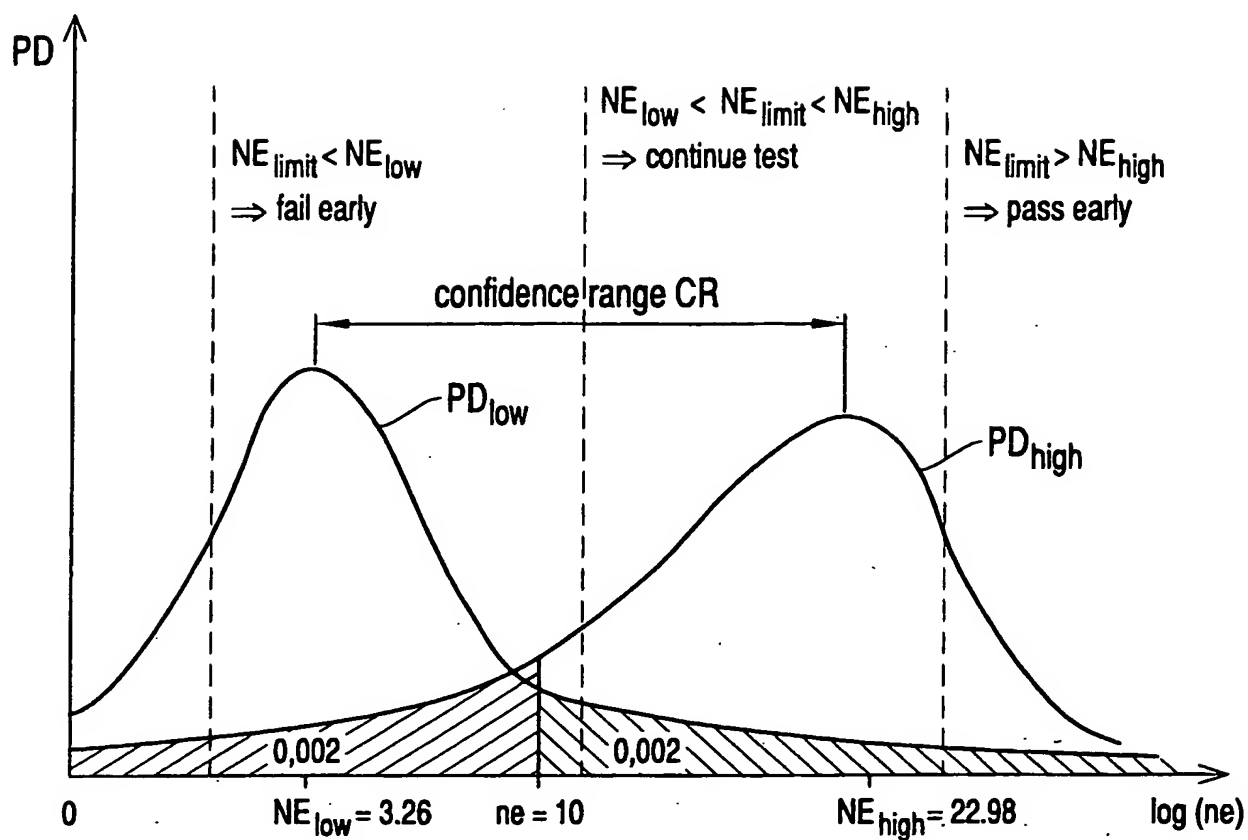


Fig. 1

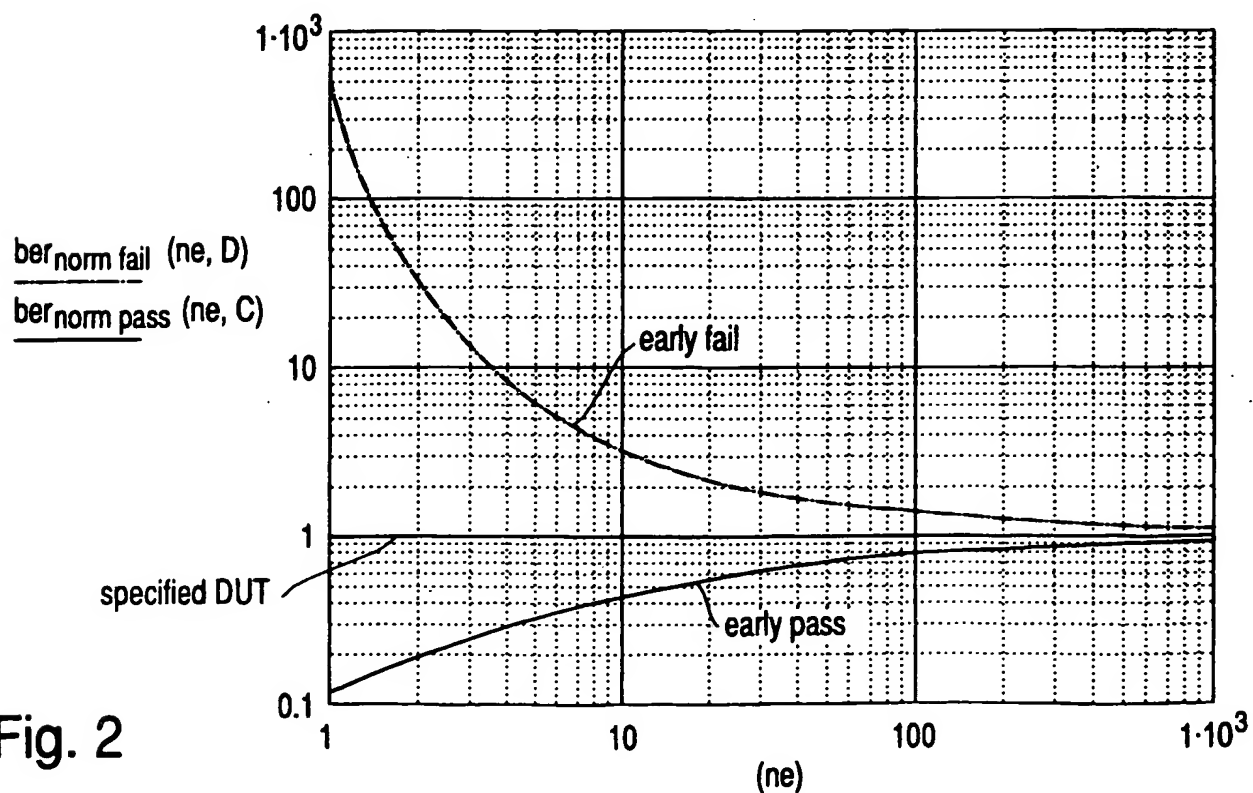


Fig. 2

2/3

BER limit = 0.2 (1/5) Actual BER = 0.25 (1/4)

Number of sample,	1	2	3	4	5	6	7	8	9	10 etc...
Sequence, 0: correct, 1: error	0	1	0	0	0	1	0	0	0	1
BER		1/2	1/3	1/4	1/5	2/6	2/7	2/8	2/9	3/10
BER _{norm}		5/2	5/3	5/4	5/5	10/6	10/7	10/8	10/9	15/10

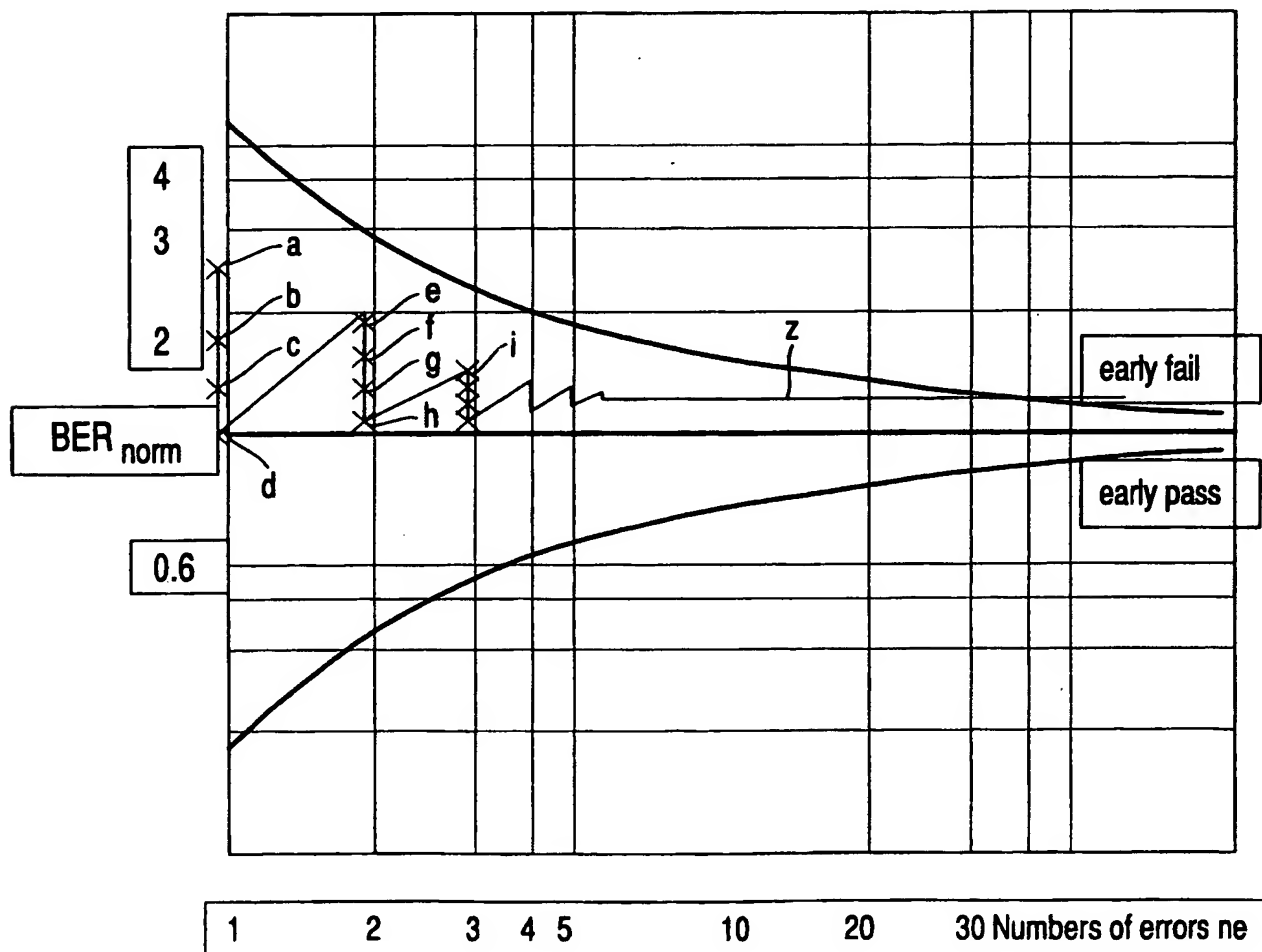


Fig. 3

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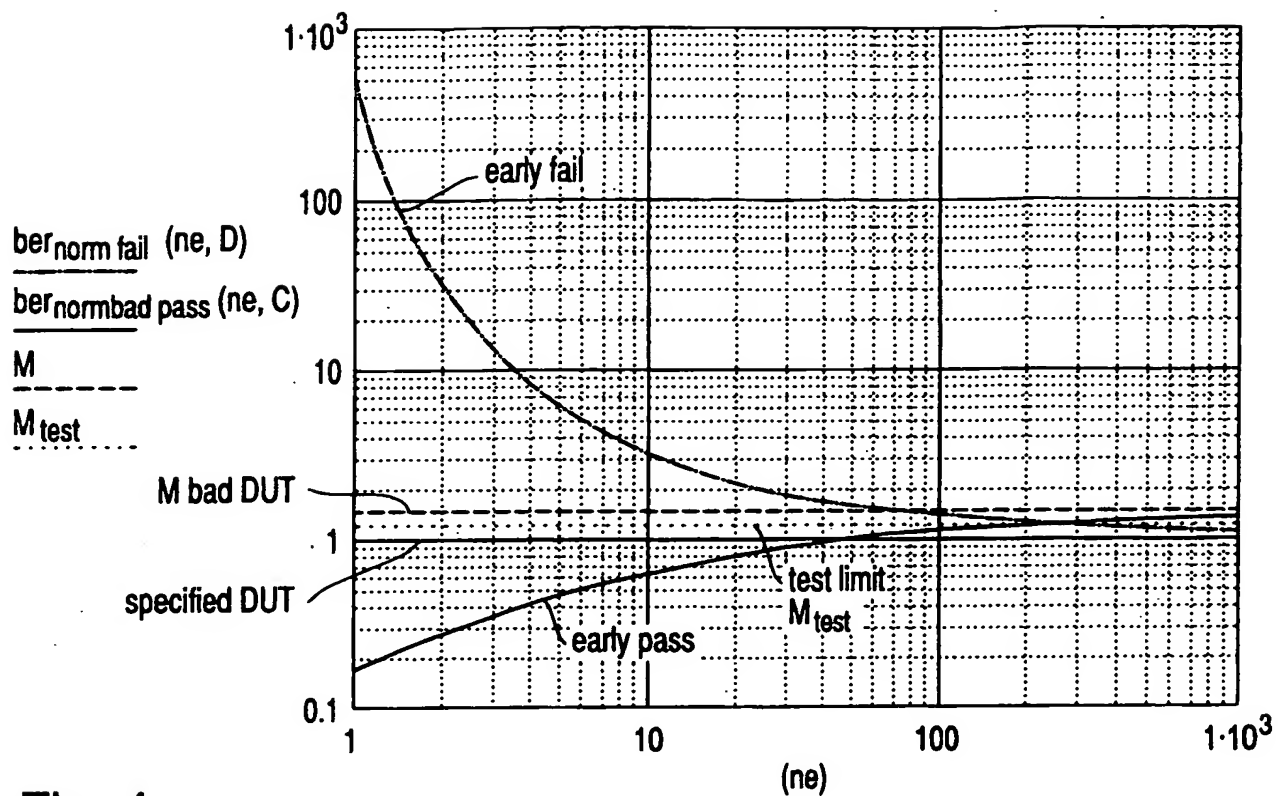


Fig. 4

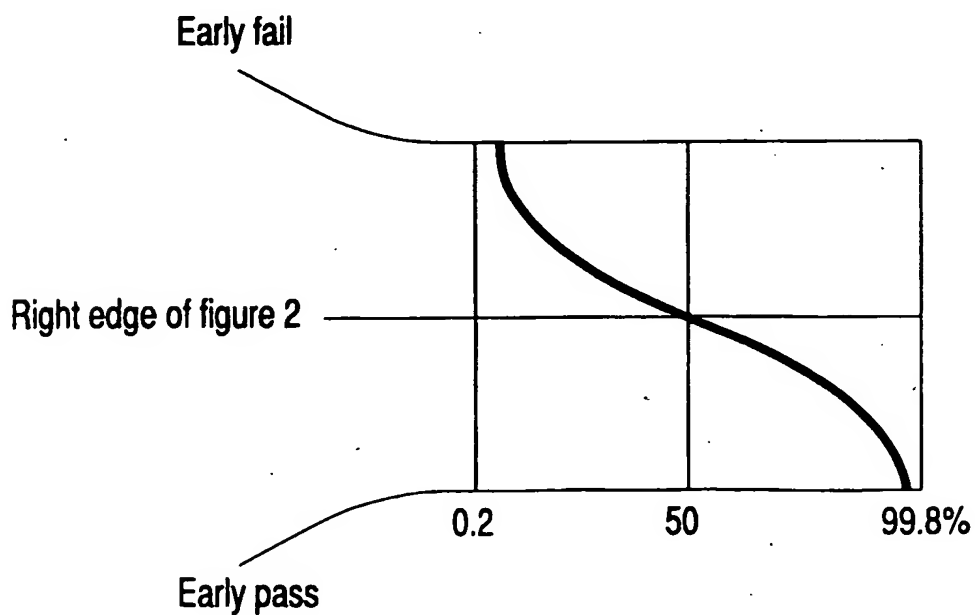


Fig. 5

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 02/02252

A. CLASSIFICATION OF SUBJECT MATTER
 IPC 7 H04L1/24 H04B17/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H04L H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 606 563 A (LEE CHRIS E ET AL) 25 February 1997 (1997-02-25) * abstract * column 1, line 41 - line 56 column 2, line 31 - column 3, line 16 column 3, line 31 - line 54 figures 1,2	1,4
A	EP 0 954 117 A (ICO SERVICES LTD) 3 November 1999 (1999-11-03) * abstract * column 3, line 27 - column 4, line 19 column 10, line 11 - line 40 figure 7	1,4

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

26 June 2002

Date of mailing of the international search report

03/07/2002

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 02/02252

Patent document cited in search report		Publication date		Patent family member(s)	Publication date
US 5606563	A	25-02-1997	CA	2159763 A1	19-11-1996
EP 0954117	A	03-11-1999	EP	0954117 A1	03-11-1999
			JP	2000059862 A	25-02-2000

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